# Dynamic Structural Response Of An Aircraft Wing Using Ansys

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## Abstract

*The objective of this project is to analyse the dynamic structural response of an aircraft wing and to simulate it for various boundary conditions. The analysis has been done for two different wing and material properties and the comparison between the results has been studied. This report briefly explains aircraft wing vibration, finite element method and its application using ANSYS. The analysis is carried out in ANSYS 13.0. The loading conditions are the self-weight of the wing. The output extracted is the mode shapes of the wing at different frequencies.*

***Keyword:Dynamics structural response, Vibration, FEM, Mode shapes***



## 1. Introduction

The dynamic structural response of on aircraft wing is to ensure the behaviour of the structure in which the vibration tends to occur. This analysis is considered as the modal analysisthe goal of modal analysis in structural mechanics is to determine the natural mode shapes and frequencies of an object or structure during freevibration. It is common to use the finite element method (FEM) to perform this analysis because, like other calculations using the FEM, the object being analysed can havearbitrary shape and the results of the calculations are acceptable. The types of equations whicharise from modal analysisare those seen in Eigen systems. The physical interpretation of the eigenvalues and eigenvectorswhich come from solving the system are that they represent the frequencies and corresponding mode shapes.

This document will attempt to explain some concepts about how structures vibrate and the use of some of the tools to solve structural dynamic problems. The intent of this document is to simply identify how structures vibrate from a non-mathematical perspective.The analysis of the signals typically relies on Fourier analysis. The resulting transfer function will show one or moreresonances, whose frequency can be estimated from the nodal solution.

## 2. Vibration Theory

Mathematical techniques allow us to quantify total displacement caused by all vibrations, to convert the displacement measurements to velocity or acceleration, to separate these data into their components through the use of FFT analysis, and to determine the amplitudes and phases of these functions. Such quantification is necessary if we are to isolate and correct abnormal vibrations in machinery.

### 2.1Periodic Motion

Vibration is a periodic motion, or one that repeats itself after a certain interval of time called the period, ***T.***

### 2.2 Harmonic Motion

It is the simplest kind of periodic motion or vibration. Harmonic motions repeat each time the rotating element or machine component completes one complete cycle.

The maximum value of the displacement is X, which is also called the amplitude. The period, ***T,*** is usually measured in seconds; its reciprocal is the frequency of the vibration, measured in cycles-per-second (cps) or Hertz (Hz).

$$f = \frac{1}{T}$$

Another measure of frequency is the circular frequency, ω**,** measured in radians per second.

$$\omega = 2\pi f$$

For rotating machinery, the frequency is often expressed in vibrations per minute (vpm) or

$$VPM = \frac{\omega}{\pi}$$

By definition, velocity is the first derivative of displacement with respect to time. For a harmonic motion, the displacement equation is:

$$X = X_0 \sin(\omega t)$$

The first derivative of this equation gives us the equation for velocity:

$$v = \frac{dX}{dt} = \omega x0\cos(\omega t)$$

This relationship tells us that the velocity is also harmonic if the displacement is harmonic and has a maximum value or amplitude of $-\omega X_0$.
By definition, acceleration is the second derivative of displacement (i.e., the first derivative of velocity) with respect to time.
This function is also harmonic with amplitude of $\omega^2 X_0$.

## 2.3No harmonic Motion
In most machinery, there are numerous sources of vibrations; therefore, most time domain vibration profiles are No harmonic. While all harmonic motions are periodic, not every periodic motion is harmonic.

## 2.4 Frequency
Frequency is the number of occurrences of a repeating event per unit time. It is also referred to as temporal frequency. The period is the duration of one cycle in a repeating event, so the period is the reciprocal of the frequency.

## 2.5Amplitude
Amplitude refers to the maximum value of a motion or vibration. This value can be represented in terms of displacement (mils), velocity (inches per second), or acceleration (inches per second squared), each of which is discussed in more detail in the following section on Maximum Vibration Measurement.
Amplitude can be measured as the sum of all the forces causing vibrations within a piece of machinery (broadband), as discrete measurements for the individual forces (component), or for individual user-selected forces (narrowband). Broadband, component, and narrowband are discussed in a later section titled Measurement Classifications. Also discussed in this section are the common curve elements: peak-to-peak, zero-to-peak, and root-mean-square.

## 2.6Displacement
Displacement is the actual change in distance or position of an object relative to a reference point and is usually expressed in units of mils, 0.001 inch. For example, displacement is the actual radial or axial movement of the shaft in relation to the normal centreline usually using the machine housing as the stationary reference. Vibration data, such as shaft displacement measurements acquired using a proximity probe or displacement transducer should always be expressed in terms of mils, peak to peak.

## 2.7 Velocity
Velocity is defined as the time rate of change of displacement (i.e., the first derivative), and is usually expressed as inches per second (in/sec). In simple terms, velocity is a description of how fast a vibration component is movingrather than how far, which is described by displacement.
Used in conjunction with zero-to-peak (PK) terms, velocity is the best representation of the true energy generated by a machine when relative or bearing cap data are used. In most cases, peak velocity values are used with vibration data between 0 and 1000 Hz. These data are acquired withmicroprocessor-based, frequency-domain systems.

## 2.8 Acceleration
Acceleration is defined as the time rate of change of velocity (i.e., second derivative of displacement),and is expressed in units of inches per second squared (in. / $sec^2$). Vibration frequencies above 1000 Hz should always be expressed as acceleration. Acceleration is commonly expressed in terms of the gravitational constant, g, which is 32.17 ft/$sec^2$. In vibration analysis applications, acceleration is typically expressed in terms of g-RMS or g-PK. These are the best measures of the force generated by a machine, a group of components, or one of its components.



## 3. MODEL 1
In this paper, taper wing model is taken as Model 1.

## 3.1 Specification of Taper wing model

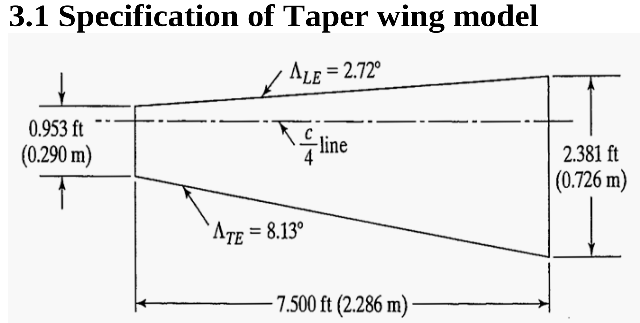


Fig.1 Taper wing model dimensions

- Airfoil profile chosen for design :NACA65210
- Zero-lift angle of attack($\alpha_{0L}$) :1.2°
- Semi span length of the wing :2.286 m
- Root chord width :0.726 m
- Tip chord width :0.290 m
- Aspect Ratio :9.0
- Taper Ratio :0.4

## 3.Solid model of Taper Wing

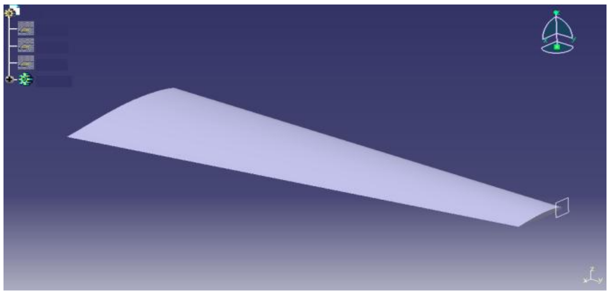

Fig.2 Taper Wing solid model in CATIA

### 3.2.1Boundary condition for model 1 analysis

| S. No | Material | Young's Modulus N/m$^2$ | Density Kg/m$^3$ | Poisson's Ratio |
|---|---|---|---|---|
| 1 | Aluminum | 7.20E+10 | 2810.00 | 0.33 |
| 2 | Titanium | 1.10E+11 | 4420.00 | 0.34 |

### 3.3 Analysis Taper Wing result showing deflection (aluminium)

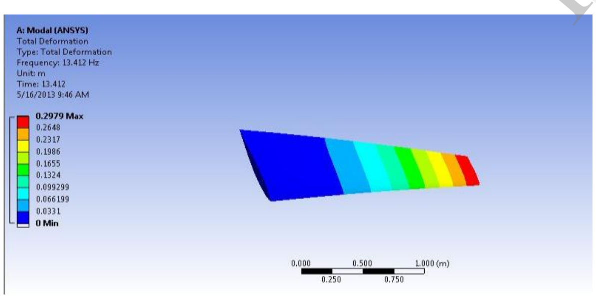


Fig.3 Maximum deflection of Wing (aluminium)

### 3.4 Analysis of Taper Wing result showing deflection (titanium)

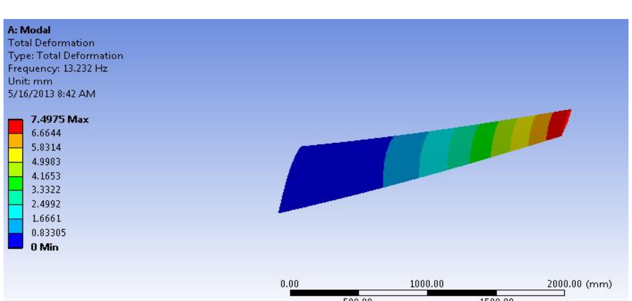


Fig.4 Maximum deflection of Wing(Titanium)

### 3.5 Analysis results for model 1

**Natural frequency:**

Taper wing (aluminium) :13.412Hz
Taper wing (titanium) :13.232Hz

**Max.Displacement for model**

Taper wing (aluminium) :0.2979mm
Taper wing (titanium) :7.4975mm

## 4. MODEL 2

In this paper, rectangular wing model is taken as Model 2.

### 4.1 Specification of Taper wing model

In this rectangular wing dimension is a semi span length of 2.286m and root chord and tip chord width is .726m.The air foil is used same as model 1and model 2

### 4.2 Solid model of Rectangular Wing

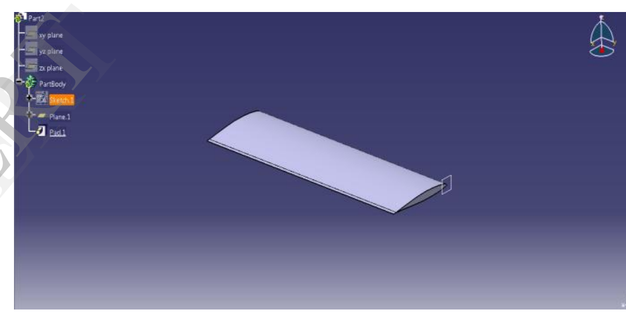

Fig.5 Rectangular wing solid model in CATIA

### 4.2.1Boundary condition for model 1 analysis

The same boundary condition used for Model 1and Model 2

| S. No | Material | Young's Modulus N/m$^2$ | Density Kg/m$^3$ | Poisson's Ratio |
|---|---|---|---|---|
| 1 | Aluminum | 7.20E+10 | 2810.00 | 0.33 |
| 2 | Titanium | 1.10E+11 | 4420.00 | 0.34 |

### 4.3 Analysis ofrectangular Wing result showing deflection (aluminium)

The below figure shows the deflection caused due to the natural frequency at the Mode 1 by Using aluminium material

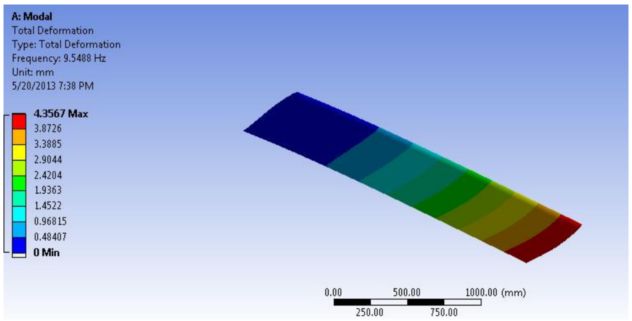


Fig.7 Maximum deflection of wing (Aluminium)

### 4.4 Analysis rectangular Wing result showing deflection (titanium)

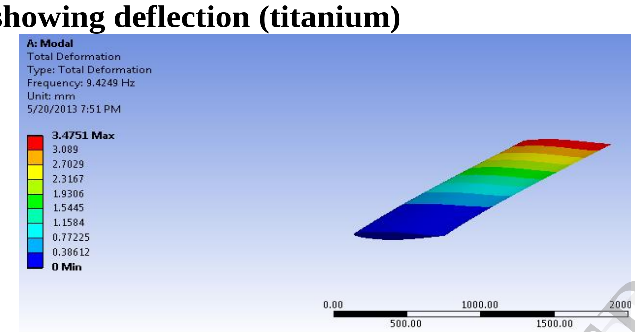


Fig.8 Maximum deflection of wing(Titanium)



### 4.5 Analysis results for model 2

**Natural frequency:**

Rectangular wing (aluminium) :9.5488Hz

Rectangular wing (titanium) :9.4249Hz

**Max.Displacement for model**

Rectangular wing (aluminium) :4.3567mm

Rectangular wing (titanium) :3.4751mm

## 5. Comparison of Model 1 and Model 2Results

The comparison of model 1natural frequency and model 2 natural frequency

### 5.1 Analysis results(Natural frequency)

| s.no | Taper wing (aluminium) Hz | Taper wing (titanium) Hz | Rectangularwing (aluminium)Hz | Rectangular wing (titanium) Hz |
|---|---|---|---|---|
| 1 | 13.412 | 13.232 | 9.5488 | 9.4249 |

### 5.2 Analysis results (max displacement)

| s.no | Taper wing (aluminium) mm | Taper wing (titanium) Mm | Rectangularwing (aluminium)mm | Rectangular wing (titanium) mm |
|---|---|---|---|---|
| 1 | 9.4031 | 7.4975 | 4.3567 | 3.4751 |

## 6. Conclusion

This paper concludes that, from the above modal analysis, the result shows that the natural frequency calculated for taper wing is higher than the normal rectangular wing and also the displacement for taper wing is less than the rectangular wing

## 7. References

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